US009450197B2

(12) United States Patent
Min

(10) Patent No.: US 9,450,197 B2
(45) Date of Patent: Sep. 20, 2016

(54) FLEXIBLE DISPLAY APPARATUS

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/617,199**

(22) Filed: **Feb. 9, 2015**

(65) **Prior Publication Data**

US 2016/0043153 A1 Feb. 11, 2016

(30) **Foreign Application Priority Data**

Aug. 8, 2014 (KR) 10-2014-0102616

(51) **Int. Cl.**
H01L 27/32 (2006.01)
H01L 51/00 (2006.01)

(52) **U.S. Cl.**
CPC ***H01L 51/0097*** (2013.01); ***H01L 27/3244*** (2013.01); *H01L 2251/5338* (2013.01); *H01L 2251/5369* (2013.01); *H01L 2251/558* (2013.01)

(58) **Field of Classification Search**
CPC H01L 51/0097
See application file for complete search history.

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(57) **ABSTRACT**

A flexible display apparatus includes a plurality of pixels on a display area of a flexible substrate. A pad area is on a non-display area of the flexible substrate. A driving integrated circuit is electrically connected to the pad area. A support layer is on a surface of the flexible substrate opposite to a surface facing the driving integrated circuit. An adhesion layer attaches the support layer to the substrate. The adhesion layer has a first thickness in an area corresponding to the driving integrated circuit, and a second thickness in another area. The second thickness is less than the first thickness.

20 Claims, 5 Drawing Sheets

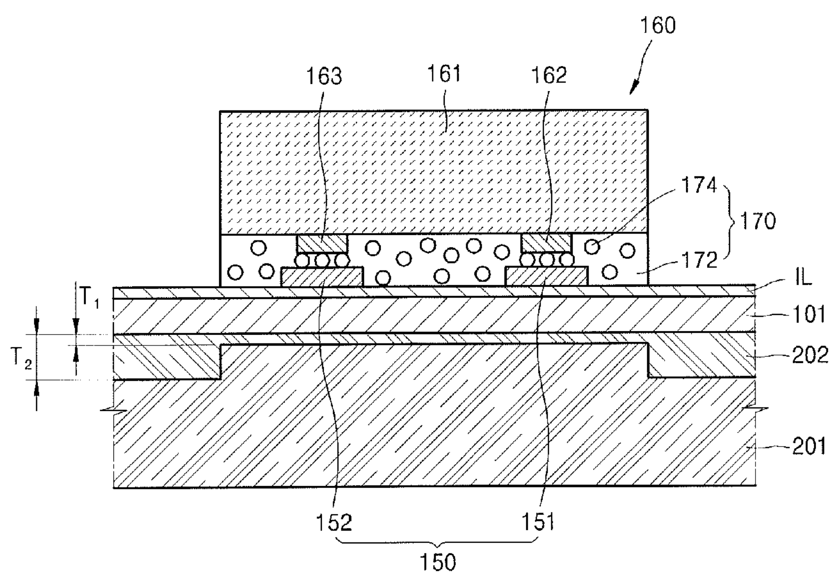
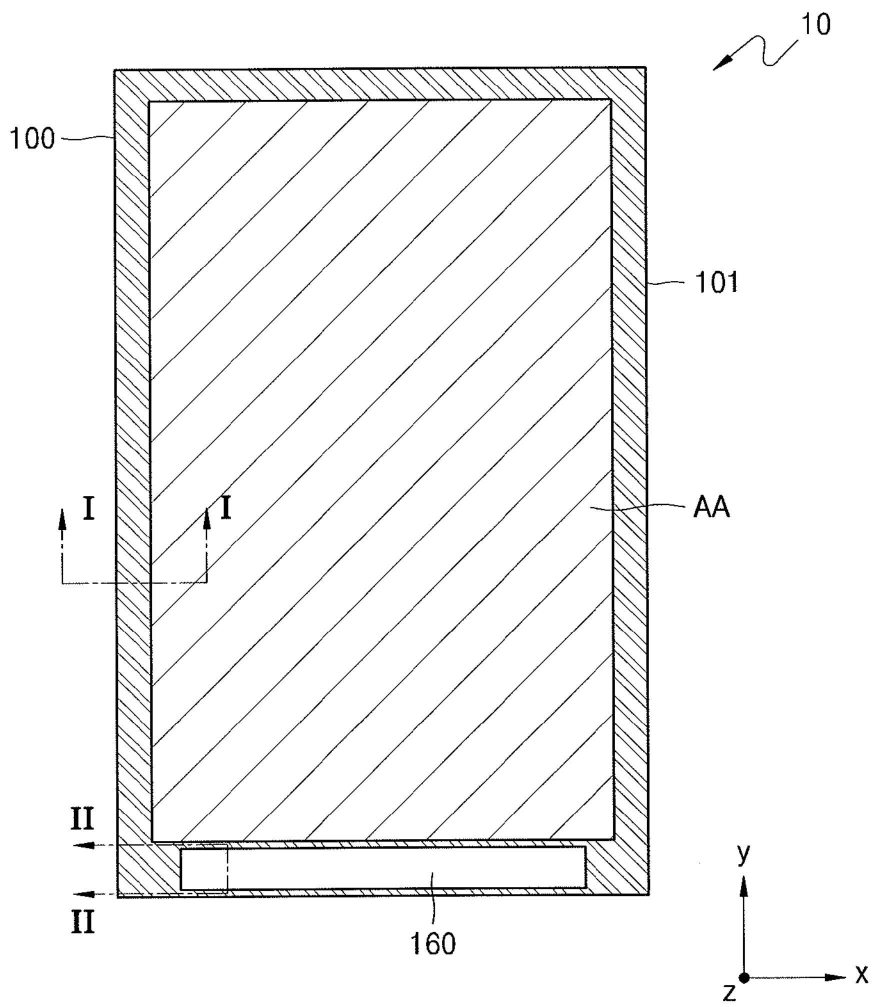


FIG. 1



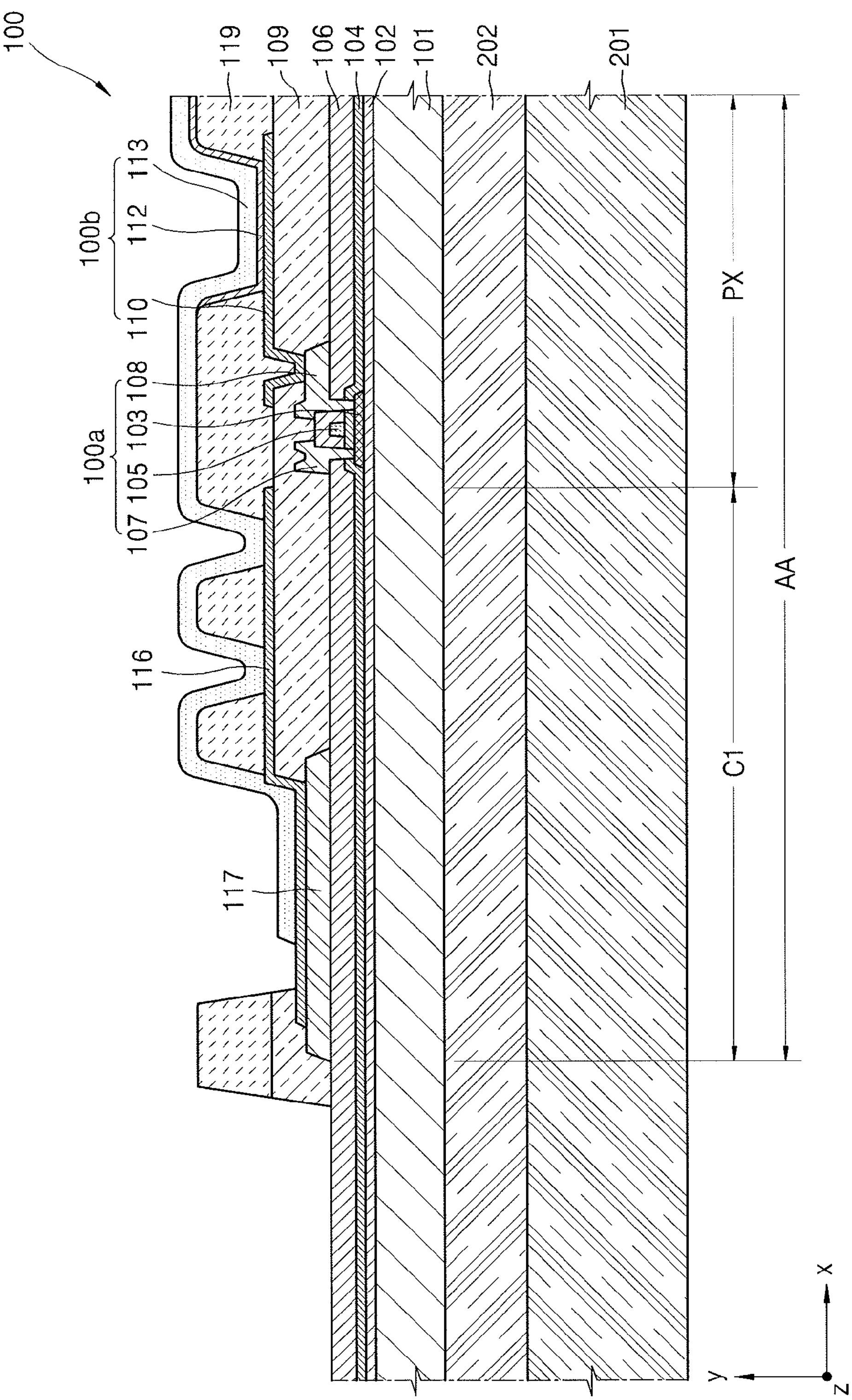

100
119
109
106
104
102
101
202
201
100b
113
112
110
100a
108
103
105
107
116
117
PX
C1
AA
x
y
z

FIG. 2

FIG. 3

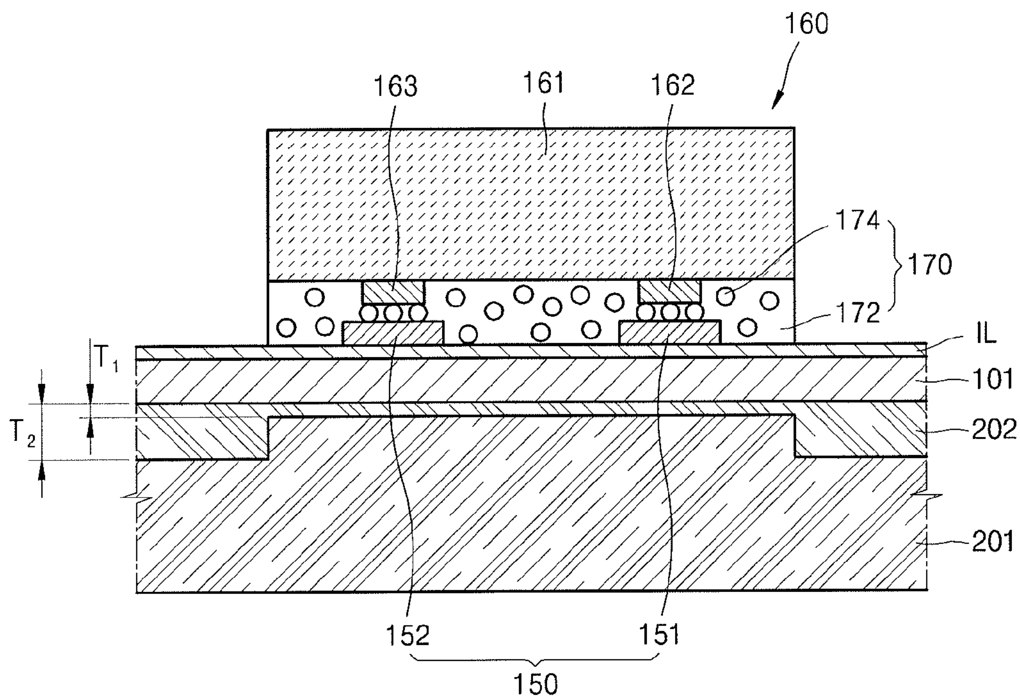


FIG. 4

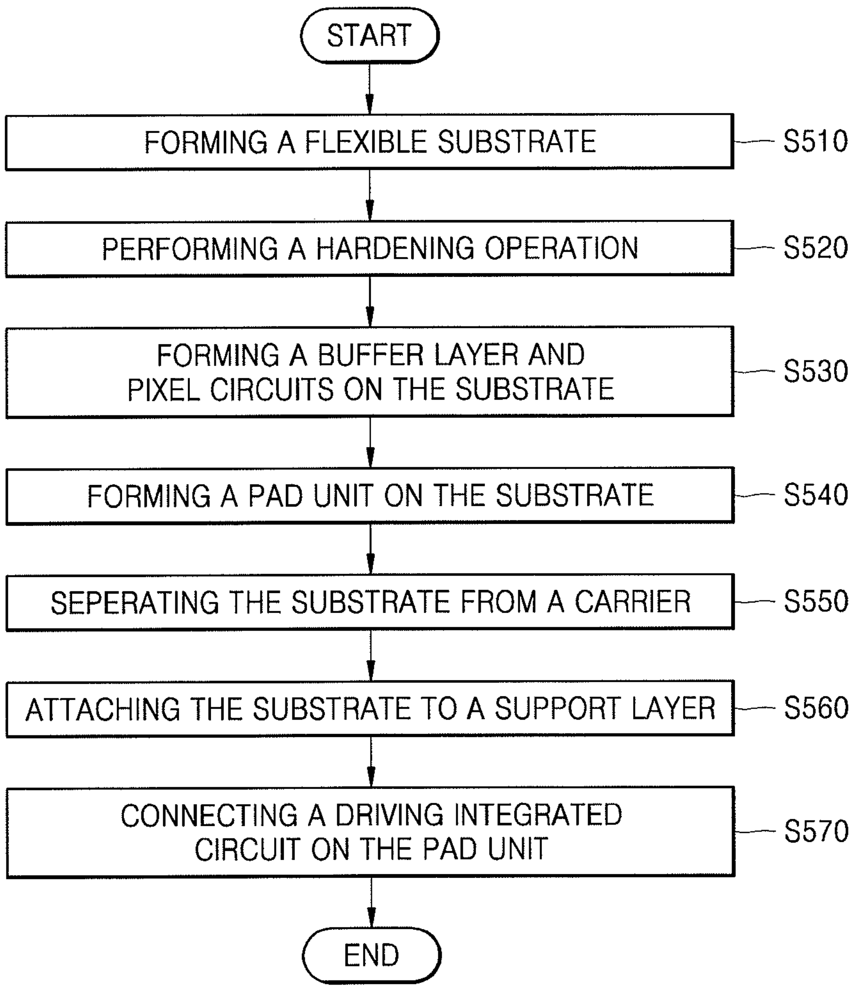
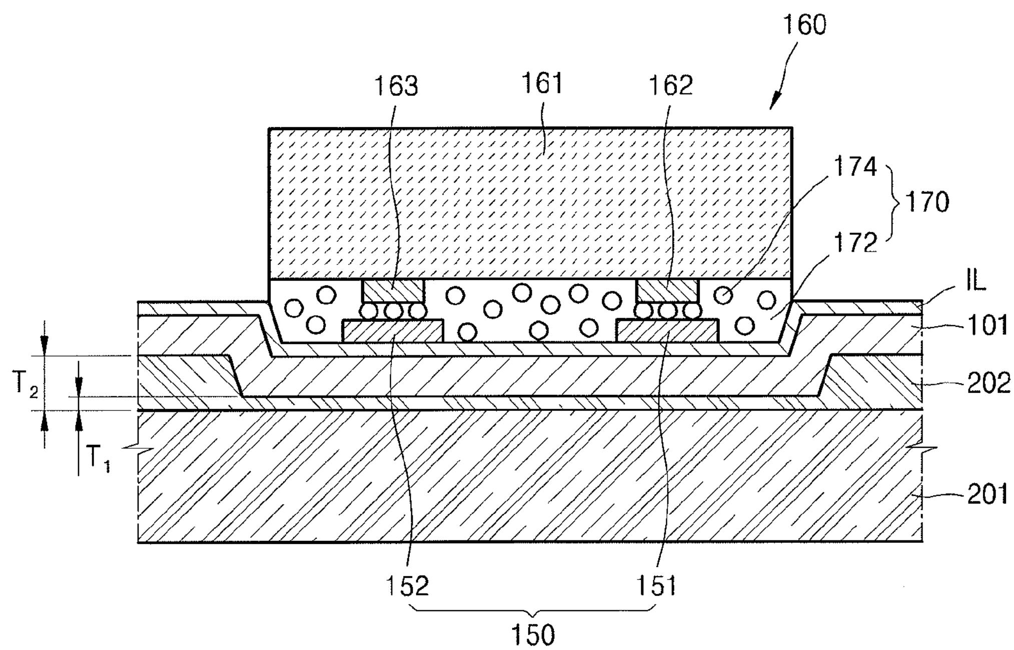

START
FORMING A FLEXIBLE SUBSTRATE
S510
PERFORMING A HARDENING OPERATION
S520
FORMING A BUFFER LAYER AND PIXEL CIRCUITS ON THE SUBSTRATE
S530
FORMING A PAD UNIT ON THE SUBSTRATE
S540
SEPERATING THE SUBSTRATE FROM A CARRIER
S550
ATTACHING THE SUBSTRATE TO A SUPPORT LAYER
S560
CONNECTING A DRIVING INTEGRATED CIRCUIT ON THE PAD UNIT
S570
END

FIG. 5



FLEXIBLE DISPLAY APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

Korean Patent Application No. 10-2014-0102616, filed on Aug. 8, 2014, and entitled, "Flexible Display Apparatus," is incorporated by reference herein in its entirety.

BACKGROUND

1. Field

One or more embodiments described herein relate to a flexible display apparatus.

2. Description of the Related Art

A flexible display has been developed which may be bent or rolled up. This display includes a display unit on a thin and flexible substrate. The display unit displays images based on a signal applied from a driving integrated circuit.

The driving integrated circuit may be mounted on a display panel using a chip-on-glass (COG) method, a tape carrier package (TCP) method, or a chip-on-film (COF) method. The COG method is preferred to the TCP and COF methods because the COG method is simpler than the TOP and COF methods.

In the COG method, a rigid driving integrated circuit is placed on a glass having a circuit pattern. The rigid driving integrated circuit is then heated and pressed to mount the integrated circuit on the glass. When the driving integrated circuit is pressed on the glass, the glass is not transformed in terms of its shape because the glass is also rigid. The driving integrated circuit may therefore be effectively mounted on the glass.

However, when pressure is applied to attach a driving integrated circuit on a flexible display, the area of the flexible display to which the driving integrated circuit is attached is compressed. Because of the flexible properties of this type of display, the driving integrated circuit may not be securely attached. As a result, a malfunction may occur, e.g., a failure to supply current to the driving integrated circuit may occur.

SUMMARY

In accordance with one embodiment, a flexible display apparatus includes a flexible substrate, a plurality of pixels on a display area of the flexible substrate, a pad area on a non-display area of the flexible substrate; a driving integrated circuit electrically connected to the pad area, a support layer on a surface of the flexible substrate opposite to a surface facing the driving integrated circuit, and an adhesion layer attaching the support layer to the substrate. The adhesion layer has a first thickness in an area corresponding to the driving integrated circuit and a second thickness in another area, and wherein the second thickness is less than the first thickness.

The first thickness may be less than 12% of the second thickness. The support layer may project from the first area toward the flexible substrate. An upper surface of the adhesion layer may be substantially flat. The substrate may include a concave area in the first area. The driving integrated circuit may be within the concave area.

The pad area may include a plurality of pads, and the driving integrated circuit may include an integrated circuit chip and a plurality of bumps electrically connected to the plurality of pads. The pad area may be coupled to the driving integrated circuit by a conducting film. The conducting film may include an adhesive insulating resin layer and conductive balls dispersed in the adhesive insulating resin layer, each of the conductive balls may have the diameter of about 2 μm to about 4 μm, and the plurality of pads and the plurality of bumps may be electrically connected via the conductive balls.

The first thickness may be less than an average diameter of the conductive balls. The adhesion layer may include one or more getters. The flexible substrate may be a single layer including polyimide. The support layer may include at least one of polyethyleneterepthalate (PET), polystyrene (PS), polyethylene napthalate (PEN), polyethersulfone (PES), or polyethylene (PE).

Each pixel includes an organic light-emitting device, and a thin film transistor electrically connected to the organic light-emitting device. The thin film transistor may include an active layer, a gate electrode, a source electrode, and a drain electrode, and the pad area may include a same material as the source electrode and the drain electrode. The apparatus may include an encapsulation layer encapsulating the display area, wherein the encapsulation layer may include an inorganic layer and an organic layer.

In accordance with another embodiment, a display includes a flexible substrate; a support layer on the flexible substrate; an integrated circuit on the flexible substrate; and an adhesion layer between the support layer and the flexible substrate, wherein the adhesion layer has a first thickness in an area corresponding to the integrated circuit and a second thickness in another area, the second thickness different from the first thickness in a second area. The second thickness may be less than the first thickness. The support layer and the integrated circuit may be on opposing surfaces of the flexible substrate. The display may include an intermediate layer between the integrated circuit and the flexible substrate, the intermediate layer may including conductive particles dispersed throughout a host material.

BRIEF DESCRIPTION OF THE DRAWINGS

Features will become apparent to those of skill in the art by describing in detail exemplary embodiments with reference to the attached drawings in which:

FIG. **1** illustrates an embodiment of a flexible display;

FIG. **2** illustrates an example of the display along section line I-I in FIG. **1**;

FIG. **3** illustrates an example of the display along section line II-II in FIG. **1**;

FIG. **4** illustrates a method for manufacturing a flexible display apparatus;

FIG. **5** illustrates another example of the display along section line II-II in FIG. **1**.

DETAILED DESCRIPTION

Example embodiments are described more fully hereinafter with reference to the accompanying drawings; however, they may be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey exemplary implementations to those skilled in the art.

In the drawings, the dimensions of layers and regions may be exaggerated for clarity of illustration. It will also be understood that when a layer or element is referred to as being "on" another layer or substrate, it can be directly on the other layer or substrate, or intervening layers may also be present. Further, it will be understood that when a layer is referred to as being "under" another layer, it can be directly under, and one or more intervening layers may also be present. In addition, it will also be understood that when a layer is referred to as being "between" two layers, it can be the only layer between the two layers, or one or more intervening layers may also be present. Like reference numerals refer to like elements throughout.

FIG. **1** illustrates an embodiment of a flexible display apparatus **10**. FIG. **2** illustrates one example of a cross-sectional structure the flexible display apparatus **10** taken along line I-I in FIG. **1**. FIG. **3** is another example of a cross-sectional structure of the flexible display apparatus **10** taken along line II-II of FIG. **1**.

Referring to FIGS. **1** to **3**, the flexible display apparatus **10** includes a flexible display panel **100** and a driving integrated circuit **160**, which applies an electric signal to the flexible display panel **100**. The flexible display panel **100** includes a display area AA to display an image and a pad unit **150**. The pad unit has a plurality of pads **151** and **152** outside the display area AA.

A circuit unit C**1** that applies an electric signal to a plurality of pixel units PX may be inside the display area. Each of the pixel units PX may include a thin film transistor **100***a* and an organic light-emitting device **100***b*. The circuit unit C**1** may include various circuit patterns such as but not limited to a power supply pattern and an electrostatic prevention pattern.

The thin film transistor **100***a* may be on a first surface of a substrate **101**, and may include an active layer **103**, a gate electrode **105**, a source electrode **107**, and a drain electrode **108**.

The substrate **101** may be a flexible substrate made of a flexible material, e.g., plastic. For example, the substrate **101** may include one or more of polyethersulphone (PES), polyacrylate (PAR), polyetherimide (PEI), polyethylene napthalate (PEN), polyethyleneterepthalate (PET), polyphenylene sulfide (PPS), polyallylate, polyimide (PI), polycarbonate (PC), or poly(aryleneether sulfone), or a combination thereof.

Among these examples, polyimide (PI) has a significant mechanical strength and flexibility and a high heat resistance, e.g., one that can withstand a maximum possible temperature (e.g., about 450° C.) during a manufacturing process. Because of this high heat resistance, the substrate **101** is not deformed by heat generated during a heating process during manufacture, or by the weight of devices and layers formed on the substrate **101** during processes for forming the thin film transistor **100***a* and the organic light-emitting device **100***b* on the substrate **101**. The flexible display panel **100** may therefore be manufactured in a stable manner.

A buffer layer **102** prevents foreign material from infiltrating through the substrate **101**, and also provides a flat surface on the upper portion of the substrate **101**. The buffer layer **102** may be formed of a variety of materials that are suitable for the above-described functions. For example, the buffer layer **102** may include one or more inorganic materials including but not limited to silicon oxide, silicon nitride, silicon oxynitride, aluminum oxide, aluminum nitride, or titanium oxide or titanium nitride, and/or one or more organic materials including but not limited to polyimide, polyesther, or acryl. The buffer layer **102** may have a multi-layer structure in one embodiment.

The active layer **103** may include, for example, an inorganic semiconductor material such as amorphous silicon or polysilicon, an organic semiconductor, or an oxide semiconductor The active layer **103** includes a channel area between a source area and a drain area.

If the active layer **103** includes polysilicon, various crystallization methods may be used to form the active layer. Examples of these methods include a rapid thermal annealing (RTA) process, a solid phase crystallization (SPC) method, an excimer laser annealing (ELA) method, a metal induced crystallization (MIC) method, a metal induced lateral crystallization (MILC) method, or a sequential lateral solidification (SLS) method. One or more of these methods may be used to form amorphous silicon and to convert the amorphous silicon into polysilicon by crystallization.

If the substrate **101** is or includes a plastic substrate using polyimide, a low temperature poly-silicon (LTPS) process may be used as a crystallization method. The LTPS process may prevent the substrate **101** from being exposed to high temperature of 300° C. or greater by irradiating a laser beam for a short time during crystallizing amorphous silicon.

A gate insulating layer **104** is on the upper portion of the active layer **103**. The gate insulating layer **104** may include an organic material or an inorganic material (e.g., SiNx, or SiO_2) and services to insulate the active layer **103** and the gate electrode **105**.

A gate electrode **105** is on a predetermined area of the upper portion of the gate insulating layer **104**. The gate electrode **105** is connected to a gate line that applies an on/off signal to the thin film transistor **100***a*. The gate electrode **105** may include one or more of gold (Au), silver (Ag), copper (Cu), nickel (Ni), platinum (Pt), palladium (Pd), aluminum (Al), or molybdenum (Mo), or alloys such as Al:Nd or Mo:W alloy.

An interlayer insulating layer **106** is on the gate electrode **105**. The interlayer insulating layer **106** may include an inorganic material (e.g., SiN_x, or SiO_2) to insulate the gate electrode **105** from the source electrode **107** and the drain electrode **108**. The source electrode **107** and the drain electrode **108** are on the interlayer insulating layer **106**. The source electrode **107** and the drain electrode **108** may include one or more metals such as Al, Pt, Pd, Ag, magnesium (Mg), Au, Ni, neodymium (Nd), iridium (Ir), chromium (Cr), Li, calcium (Ca), Mo, titanium (Ti), tungsten (W), or Cu.

The interlayer insulating layer **106** and the gate insulating layer **104** may include holes that expose the source area and the drain area of the active layer **103** to the source electrode **107** and drain electrode **108**, so that the source electrode **107** and the drain electrode **108** contact the source area and the drain area of active layer **103** through the holes.

FIG. **2** illustrates an example of the thin film transistor **100***a* that is a top-gate type including the active layer **103**, the gate electrode **105**, the source electrode **107**, and the drain electrode **108** in sequence. The gate electrode **105** may be under the active layer **103**. The thin film transistor **100***a* is electrically connected to an organic light-emitting device **100***b* to drive the organic light-emitting device **100***b*, and a planarization layer **109** covers the thin film transistor **100***a* for protection.

The planarization layer **109** may include an organic insulating layer and/or an organic insulating layer. The inorganic insulating layer may include, for example, one or more of SiO_2, SiNx, SiON, Al_2O_3, TiO_2, tantalum oxide (Ta_2O_5), HfO_2, ZrO_2, BST, or PZT. The organic insulating layer may include, for example, one or more commercial polymers such as poly-methyl methacrylate (PMMA) or polystyrene (PS), a polymer derivative having a phenol-based group, an acryl-based polymer, an imide-based polymer, an aryl ether-based polymer, an amide-based polymer, a fluorine-based polymer, a p-xylene-based polymer, or a vinyl alcohol-based polymer, or a blend thereof. Also, the planarization layer **109** may be formed in a composite laminate of the inorganic insulating layer and the organic insulating layer.

The organic light-emitting device **100***b* is on the planarization layer **109**. The organic light-emitting device **100***b* may include an intermediate layer **112** between a pixel electrode **110** and a common electrode **113**. The pixel electrode **110** may be on the planarization layer **109**, and electrically connected to the drain electrode **108** by passing through the planarization layer **109**.

The pixel electrode **110** may be a reflective electrode. The pixel electrode **110** may include a reflective film including one or more of Ag, Mg, Al, Pt, Pd, Au, Ni, Nd, Ir, or Cr, or a compound thereof, and a transparent or translucent electrode layer on the reflective film. The transparent or translucent electrode layer may include at least one of indium tin oxide (ITO), indium zinc oxide (IZO), zinc oxide (ZnO), indium oxide (In_2O_3), indium gallium oxide (IGO), or aluminum zinc oxide (AZO).

A pixel defining layer **119** is on the pixel electrode **110** as an insulating material. The pixel defining layer **119** may include one or more organic insulating materials such as but not limited to polyimide, polyamide, acrylic resin, benzocyclobutene, or phenol resin. The pixel defining layer **119** exposes a predetermined area of the pixel electrode **110** to define an area where the intermediate layer **112** is formed. The intermediate layer **112** may include an organic emission layer in the exposed area.

The organic emission layer in the intermediate layer **112** may include a low molecular weight organic material or a high molecular weight organic material. The intermediate layer **112** may include a functional layer, for example, one or more of a hole transport layer (HTL), a hole injection layer (HIL), an electron transport layer (ETL), or an electron injection layer (EIL), as well as the organic emission layer in a selective manner.

The common electrode **113** may be a transparent or translucent electrode The common electrode **113** may include a metal thin film which includes, for example, one or more of Li, Ca, LiF/Ca, LiF/Al, Al, Ag, or Mg, or a compound thereof, and which has a small work function. Also, an auxiliary electrode layer or a bus electrode may be formed with a material for forming a transparent electrode, e.g., ITO, IZO, ZnO or In_2O_3, on the metal thin film.

Thus, the common electrode **113** may transmit light emitted from an organic emission layer in the intermediate layer **112**. In other words, the light emitted from the organic emission layer may be emitted directly to the common electrode **113**, or may be reflected by the pixel electrode **110** that includes a reflective electrode. Then, the reflected light may be emitted to the common electrode **113**.

In another embodiment, the flexible display apparatus **10** may be different from a front-surface light-emitting type, e.g., may be a rear-surface light-emitting type that emits the light from the organic emission layer toward the substrate **101**. In this case, the pixel electrode **110** may include a transparent or translucent electrode, and the common electrode **113** may include a reflective electrode. Also, according to one embodiment, the flexible display apparatus **10** may be a both-surface light-emitting type that emits light from both the front and the rear surfaces.

A circuit unit C1 may include a circuit line **116** and a power line **117**, and may also include various circuit patterns such as an electrostatic prevention pattern. The circuit line **116** may include, for example, a same material as the pixel electrode **110** and may be connected to the common electrode **113**. The power line **117** may include a same material as the source electrode **107** or the drain electrode **108**.

An encapsulation layer may be on a first surface of the substrate **101** to encapsulate the display area AA. The encapsulation layer may have a layered structure of an inorganic layer and an organic layer. For example, the inorganic layer may include an inorganic material, for example, one or more of AlO_x, TiO_2, ZrO, SiO_x, AlON, AlN, SiN_x, SiO_xN_y, InO_x, or YbO_x. The organic layer may include, for example, one or more of an acryl-based resin, epoxy-based resin, silicon-based resin, allyl-based resin, polyimide, or polyethylene.

The pad unit **150** may be outside the display area AA on the first surface of the substrate **101**. The pad unit **150** may include, for example, a same material as the source electrode **107** and drain electrode **108**. The pad unit **150** may include an input pad **151** and an output pad **152**. A plurality of input pads **151** and output pads **152** may be arranged in a width direction of the flexible display apparatus **10**.

The flexible display panel **100** may include a support layer **201** and an adhesion layer **202**. The support layer may be on a second surface opposite to the first surface of the substrate **101**. The adhesion layer **202** may attach the support layer **201** to the second surface.

The support layer **201** adds thickness to the flexible display panel **100** for easier handling and may also prevent damage to (e.g., tearing of) the flexible display panel **100**. The support layer **201** may include at least one of polyethyleneterepthalate (PET), polystyrene (PS), polyethylene napthalate (PEN), polyethersulphone (PES), or polyethylene (PE).

The adhesion layer **202** is between the substrate **101** and the support layer **201**, and adheres the support layer **201** to the substrate **101**. The adhesion layer **202** may be include, for example, a pressure sensitive adhesive (PSA). Also, the adhesion layer **202** may include getters dispersed in the adhesion layer **202**. In this regard, the substrate **101** may prevent infiltration of moisture, oxygen, and the like, through the second surface of the substrate **101**.

The driving integrated circuit **160** is electrically connected to the pad unit **150** and applies electrical signals to the pad unit **150**. The driving integrated circuit **160** may include a plurality of bumps **162** and **163** electrically connected to an integrated circuit chip **161** and the plurality of pads **151** and **152**.

The driving integrated circuit **160** may be mounted on the substrate **101** using, for example, a Chip-On-Glass (COG) method. A conducting film **170** may be between the driving integrated circuit **160** and the first surface of the substrate **101**, and then pressure may be applied thereto under a predetermined temperature to mount the driving integrated circuit **160** on the substrate **101**. This method does not need a printed circuit board. Thus, high density and a larger display area AA may be achieved.

An insulating layer IL may be formed on the first surface of the substrate **101**. The insulating layer IL may be, for example, the buffer layer **102**, the gate insulating layer **104**, and the interlayer insulating layer **106**.

A conducting film **170** may be, for example, an anisotropic conductive film (ACF) including conductive balls **174** dispersed in an adhesive insulating resin layer **172**. The adhesive insulating resin layer **172** may be a film, for example, including one or more of an epoxy resin, an acryl resin, a polyimide resin, or a polycarbonate resin. The conductive balls **174** may include highly conductive materials, such as but not limited to one or more of gold, silver, nickel, or copper.

The conductive balls **174** may have predetermined diameters, e.g., about 2 μm to about 4 μm. The conductive balls **174** may contract to 80% of their original diameter by pressure after a thermo compression bonding. Thus, the aforementioned diameter of the conductive balls **174** may refer to the diameter of conductive balls **174** after the thermo compression bonding is performed to mount the driving integrated circuit **160** on the substrate **101**. If the conductive balls **174** have an oval shape after the thermo compression bonding, the diameter of each of the conductive balls **174** may correspond to the length along the short axis. Otherwise, the diameter of the conductive balls **174** may correspond to the shortest distance.

In some but not all circumstances, if the diameters of the conductive balls **174** is more than 4 μm, a short may occur among the plurality of input pads **151** or among the plurality of output pads **152** formed in a width direction of the flexible display apparatus **10**. Also, in some but not all circumstances, the diameters of the conductive balls **174** is less than 2 μm, the driving integrated circuit **160** and the pad unit **150** may not sufficiently contact each other, if at all, or the resistance between the driving integrated circuit **160** and the pad unit **150** may increase when connected.

The driving integrated circuit **160** may be mounted on the substrate **101**, for example, by the thermo compression bonding. The current may be supplied between the input pad **151** of the pad unit **150** and the input bump **162** of the driving integrated circuit **160**, and between the output pad **152** of the pad unit **150** and the output bump **163** of the driving integrated circuit **160**, via the conductive balls **174**.

Because of the flexibility of the flexible display panel **100**, the flexible display panel **100** may be pressed by the driving integrated circuit **160** during the thermo compression bonding, which is performed to mount the driving integrated circuit **160** on the substrate **101**.

The adhesion layer **202** may contract during the thermo compression bonding process used to mount the driving integrated circuit **160**, and thereby cause a failure in supplying current between the driving integrated circuit **160** and the pad unit **150**. This may occur because the adhesion layer **202** has much softer characteristic than the conductive balls **174**, the insulating layer IL, the substrate **101**, and the support layer **201** under the driving integrated circuit **160**.

To prevent the aforementioned issue, the adhesion layer **202** may have a first thickness T**1** of a first area and a second thickness T**2** of another area. The first area is an area corresponding to the driving integrated circuit **160**, and the thickness T**1** of the first area may be thinner than the second thickness T**2**.

The first thickness T**1** may be less than the average diameter of the conductive balls **174**. For example, the diameter of each of the conductive balls **174** may be, as described above, about 2 μm to about 4 μm. Thus, the first thickness T**1** may be less than 3 μm. If the first thickness T**1** is less than the average diameter of the conductive balls **174**, a failure where current is not supplied between the driving integrated circuit **160** and the pad unit **150** may be prevented, even when the adhesion layer **202** is compressed to the first thickness T**1** during mounting of the driving integrated circuit **160**.

The second thickness T**2** of the adhesion layer **202** may have a predetermined thickness (e.g., about 25 μm) to fully adhere the support layer **201** to the substrate **101**. The first thickness T**1** may be, for example, less than 12% of the first thickness T**1**.

The support layer **201** may have a convex shape projected toward the substrate **101** from an area on which the driving integrated circuit **160** is mounted. Accordingly, the adhesion layer **202** may be easily formed to have a flat upper surface, while having the first thickness T**1** only in the first area. Also, as the thickness of the support layer **201** (in the area on which the driving integrated circuit **160** is mounted) increases, the support layer **201** may have sufficient strength to withstand the pressure applied during mounting of the driving integrated circuit **160**. Thus, the driving integrated circuit **160** may be effectively attached to the substrate **101**.

FIG. **4** illustrates an embodiment of a method for manufacturing a flexible display apparatus, which, for example, may be flexible display apparatus **10**. The method includes forming the substrate **101** by coating a predetermined material (e.g., polyimide) to a predetermined thickness on a carrier substrate formed of a rigid material (e.g., glass) (S**510**). Then, the polyimide is hardened (S**520**). Subsequently, the buffer layer **102** is formed on the substrate **101**, and the thin film transistor **100***a* and the organic light-emitting device **100***b* are formed thereon (S**530**). Then, the encapsulation layer is formed to encapsulate the display area AA. The pad unit **150** may be formed when the source electrode **107** and the drain electrode **108** of the thin film transistor **100***a* are formed (S**540**).

Next, the carrier substrate is separated from the substrate **101** (S**550**). The carrier substrate may be separated from the substrate, for example, by irradiating a laser beam from under the carrier substrate. Then, the flexible display panel **100** is manufactured by separating the substrate **101** from the carrier substrate, and then attaching the substrate **101** to the support layer **201** coated with the adhesion layer **202** (S**560**).

Finally, the driving integrated circuit **160** is connected to (e.g., mounted on) the pad unit **150** using, for example, the chip-on-glass (COG) method (S**570**). The adhesion layer **202** has the first thickness T**1** in the area on which the driving integrated circuit **160** is mounted. The support layer **201** has a predetermined (e.g., a convex shape) projected toward the substrate **101** from the area on which the driving integrated circuit **160** mounted.

Therefore, even though the driving integrated circuit **160** is mounted on the flexible display panel **100** using chip-on-glass (COG) method, the adhesive strength and electrical conductivity between the driving integrated circuit **160** and the pad unit **150** may be sufficiently strong.

FIG. **5** illustrates the cross-sectional structure of another example of the flexible display apparatus **10** taken along line II-II in FIG. **1**. Referring to FIG. **5**, the insulating layer IL may be on the first surface of the substrate **101**, and the support layer **201** may be attached to the second surface of the substrate by the adhesion layer **202**.

The driving integrated circuit **160** may be mounted on the substrate **101** using a chip-on-glass (COG) method. For example, a conducting film **170** is between the driving integrated circuit **160** and the first surface of the substrate **101**, and then pressure is applied thereto under a high temperature to mount the driving integrated circuit **160** on the substrate **101**.

The conducting film **170** includes the adhesive insulating resin layer **172** and the conductive balls **174** dispersed in the adhesive insulating resin layer **172**. The input pad **151** of the pad unit **150** and the input bump **162** of the driving integrated circuit **160** are electrically connected via the conductive balls **174**. The output pad **152** of the pad unit **150** and the output bump **163** of the driving integrated circuit **160** are electrically connected via the conductive balls **174**.

The adhesion layer **202** may have a first thickness T**1** in the first area on which the driving integrated circuit **160** is mounted, and a second thickness T**2** greater than the first thickness T**1** in another area, in order to increase the adhesive strength between the substrate **101** and the support layer **201**.

For example, the first thickness T**1** may be less than 12% of the second thickness T**2**, and less than an average diameter of the conductive balls **174**. Therefore, the conductive balls **174**, which have an average diameter greater than the first thickness T**1**, may prevent a failure from occurring in which current is not supplied between the driving integrated circuit **160** and the pad unit **150**, even when the adhesion layer **202** is compressed to the first thickness T**1** during mounting of the driving integrated circuit **160**, for example, by thermo compression bonding.

The substrate **101** may include a concave portion in the first area. The concave portion may be formed larger than the driving integrated circuit **160**. The substrate **101** including the concave portion may be easily formed in the above mentioned process for manufacturing the flexible display apparatus **10**, for example, by coating the polyimide to a predetermined thickness on a carrier substrate that has a concave portion, and then hardening the polyimide.

If the substrate **101** includes a portion that is bent concavely, the adhesion layer **202** may be formed to have a first thickness T**1** only in the first area when the support layer **201** is attached to the second surface of the substrate **101**. Also, when mounting the driving integrated circuit **160**, the driving integrated circuit **160** may be easily deposited and stably maintained because the driving integrated circuit **160** may be positioned in the concave portion.

In accordance with one or more of the aforementioned embodiments, the driving integrated circuit and the flexible display panel may be strongly adhesive to each other, even when using the COG method.

Example embodiments have been disclosed herein, and although specific terms are employed, they are used and are to be interpreted in a generic and descriptive sense only and not for purpose of limitation. In some instances, as would be apparent to one of skill in the art as of the filing of the present application, features, characteristics, and/or elements described in connection with a particular embodiment may be used singly or in combination with features, characteristics, and/or elements described in connection with other embodiments unless otherwise indicated. Accordingly, it will be understood by those of skill in the art that various changes in form and details may be made without departing from the spirit and scope of the present invention as set forth in the following claims.

What is claimed is:

1. A flexible display apparatus, comprising:

a flexible substrate;

a plurality of pixels on a display area of the flexible substrate;

a pad area on a non-display area of the flexible substrate;

a driving integrated circuit electrically connected to the pad area;

a support layer on a surface of the flexible substrate opposite to a surface facing the driving integrated circuit; and

an adhesion layer attaching the support layer to the flexible substrate, wherein the adhesion layer has a first thickness in an area corresponding to the driving integrated circuit and a second thickness in another area, and wherein the first thickness is less than the second thickness.

2. The apparatus as claimed in claim **1**, wherein the first thickness is less than 12% of the second thickness.

3. The apparatus as claimed in claim **1**, wherein the support layer projects from the first area toward the flexible substrate.

4. The apparatus as claimed in claim **3**, wherein an upper surface of the adhesion layer is substantially flat.

5. The apparatus as claimed in claim **1**, wherein the flexible substrate includes a concave area in the first area.

6. The apparatus as claimed in claim **5**, wherein the driving integrated circuit is within the concave area.

7. The apparatus as claimed in claim **1**, wherein:

the pad area includes a plurality of pads,

the driving integrated circuit includes an integrated circuit chip and a plurality of bumps electrically connected to the plurality of pads, and

the adhesion layer has the second thickness in the display area.

8. The apparatus as claimed in claim **7**, wherein the pad area is coupled to the driving integrated circuit by a conducting film.

9. The apparatus as claimed in claim **8**, wherein:

the conducting film includes an adhesive insulating resin layer and conductive balls dispersed in the adhesive insulating resin layer,

each of the conductive balls has the diameter of about 2 μm to about 4 μm, and

the plurality of pads and the plurality of bumps are electrically connected via the conductive balls.

10. The apparatus as claimed in claim **9**, wherein the first thickness is less than an average diameter of the conductive balls.

11. The apparatus as claimed in claim **1**, wherein the adhesion layer includes one or more getters.

12. The apparatus as claimed in claim **1**, wherein the flexible substrate is a single layer including polyimide.

13. The apparatus as claimed in claim **1**, wherein the support layer includes at least one of polyethyleneterepthalate (PET), polystyrene (PS), polyethylene napthalate (PEN), polyethersulfone (PES), or polyethylene (PE).

14. The apparatus as claimed in claim **1**, wherein each pixel includes:

an organic light-emitting device, and

a thin film transistor electrically connected to the organic light-emitting device.

15. The apparatus as claimed in claim **14**, wherein:

the thin film transistor includes an active layer, a gate electrode, a source electrode, and a drain electrode, and

the pad area includes a same material as the source electrode and the drain electrode.

16. The apparatus as claimed in claim **1**, further comprising:

an encapsulation layer encapsulating the display area,

wherein the encapsulation layer includes an inorganic layer and an organic layer.

17. A display, comprising:

a flexible substrate;

a support layer on the flexible substrate;

an integrated circuit on the flexible substrate; and

an adhesion layer between the support layer and the flexible substrate,

wherein the adhesion layer has a first thickness in an area corresponding to the integrated circuit and a second thickness in another area, the first thickness different from the second thickness in the another area.

18. The display as claimed in claim **17**, wherein the first thickness is less than the second thickness.

19. The display as claimed in claim **17**, wherein the support layer and the integrated circuit are on opposing surfaces of the flexible substrate.

20. The display as claimed in claim **17**, further comprising:

an intermediate layer between the integrated circuit and the flexible substrate, the intermediate layer including conductive particles dispersed throughout a host material.

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